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THE DISCONFORMITY BETWEEN THE BEDFORD AND BEREA FORMATIONS IN CENTRAL OHIO[1]

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INTRODUCTION

Most of the exposures of disconformity between the Bedford and Berea formations in central Ohio, described in this paper, have been known to the writer for the last eight years. A halftone of one of these outcrops showing the irregular base of the Berea sandstone and the subjacent Bedford shale was published in December, 1904, in the *American Geologist.*[2] Lantern slides of this and other localities, showing similar structure made from photographs taken by the writer and his assistants, are in the collection of the Department of Geology of Ohio State University and have been available for use by the various teachers during the last five or six years. The writer has used them in his lectures to a succession of classes, while a large number of students have visited one or more of the localities on field trips.

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[1] Published by permission of the State Geologist of Ohio.

[2] *American Geologist*, XXXIV, Pl. XIX, Fig. 6, showing contact of Berea sandstone and Bedford shale on bank of Smith Run.

A similar disconformity was found between these formations in northern Ohio and an account of its occurrence at various localities from southwest of Cleveland eastward is contained in *Bulletin No. 15* of the Geological Survey of Ohio now passing through the press. A part of the evidence showing such a disconformity in northern and central Ohio was presented by the writer in a paper entitled the "Contact of the Bedford and Berea Formations in Ohio" at the Ohio Academy of Science meeting in Columbus on December 1, 1911. The part of that paper describing the disconformity in central Ohio makes the following portion of this article. On the day that the writer read this paper he received the October-November, 1911, number of the *Journal of Geology* containing an article by Mr. Wilbur G. Burroughs describing the unconformity between these two formations near South Amherst, Lorain County, in northern Ohio.[1]

Definition of disconformity.—The stratigraphic term disconformity is used in this article as defined by Dr. Grabau "to cover unconformable relation of strata where no discordance of dip exists,"[2] a term that was proposed by him in 1905.[3] For this type of unconformity, which has generally been called unconformity by erosion, Professor Crosby has recently proposed the name *para-unconformity*.[4]

DESCRIPTION OF SECTIONS

In this article only a few of the most interesting outcrops showing the contact of the Bedford and Berea formations on the Westerville and East Columbus quadrangles in central Ohio will be described.

Spruce Run sections.—An excellent contact occurs on the north branch of Spruce Run on the Frank E. Hoover farm, 2¼ miles southeast of Galena and 6½ miles northeast of Westerville. The contact is finely shown for some rods on the northern bank of the stream where the following section was measured:

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[1] *Journal of Geology*, XIX, 655–59.

[2] *Science*, N.S., XXIX (May 7, 1909), 750.

[3] *Ibid.*, XXII (October 27, 1905), 534.

[4] *Journal of Geology*, XX (1912), 296.

SECTION ON NORTH BRANCH OF SPRUCE RUN

No.		Thickness Feet	Total Thickness Feet
5.	*Berea sandstone.*—Top of bank. Buff sandstone containing numerous brown spots and composed of rather small grains of quartz sand as seen under lens. The base of the layer somewhat irregular with a tendency to concretionary structure......	3⅔±	11±
4.	Zone composed mostly of thin sandstone to arenaceous shale; but with the texture of the Berea. There is, however, a little soft, buff shale. The zone varies in thickness from 7 in. to 1 ft. 4 in.................	1±	7¼±
3.	Buff, quartz sandstone containing many brown spots as weathered. The top of this zone is even; but the base is irregular, making a variation in thickness from 1 ft. 5 in. to 2 ft. 10 in. The under side of this sandstone is irregular and rough as though conforming in shape to the uneven upper surface of the Bedford. The lower part, at least, of this zone is contorted as by concretionary action, so that it has the appearance of a concretionary layer. The disconformity is shown in Fig. 1 of this bank..........................	2±	6¼±
2.	*Bedford formation.*—Bank composed mainly of soft, blue to buff, argillaceous shale with occasional thin layers of sandstone varying from ½ to 1½ in. in thickness. The top of this shale is irregular as though worn by erosion; but in places the thin layers are depressed where the base of the concretionary-like superjacent layer is lowest as though pushed downward by the concretionary action. The thickness of this zone from water level to the base of the concretionary layer varies from 5 ft. 3 in. to 7 ft. 2 in....	6¼±	6¼±
1.	Farther down the stream and stratigraphically lower than the above zone in the midst of blue, argillaceous shales are blue, hard, compact sandstones, some of them several inches in thickness, which weather to brown, rotten stone indicating the presence of $CaCO_3$.		

A view of this bank is shown in Fig. 1, in which the strips of paper and the hammer indicate the undulating contact of the Bedford and

Berea formations. Above the basal, concretionary sandstone of the Berea, zone No. 3, is the zone of thin sandstone to arenaceous shale, No. 4, above which is the continuous sandstone of zone No. 5, with some concretionary structure in the lower part.

The contact of the Bedford and Berea formations is excellently shown on both banks of the south branch of Spruce Run, one mile south of the place just described on the north branch. These banks are not far below the highway on the farm owned by Mr. Frank Merrit of Delaware, now occupied by A. Looker, and about 6 miles northeast of Westerville. The southern bank shows more of the upper part of the Bedford and the following section was measured near its eastern end:

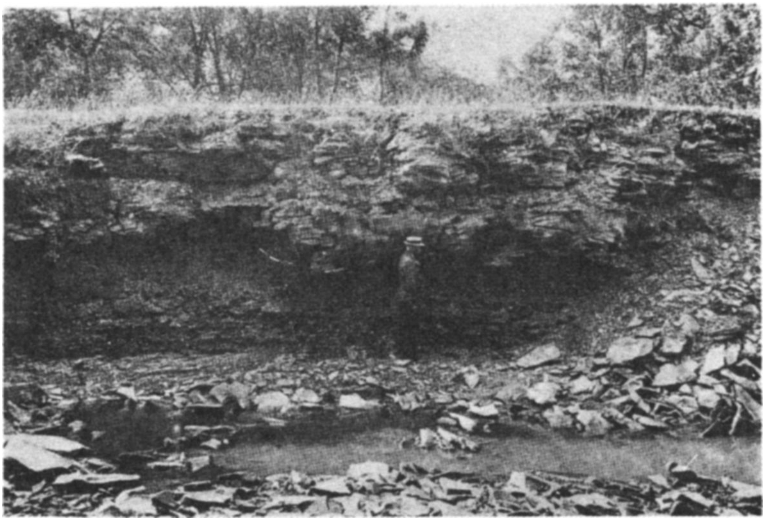

FIG. 1.—Bank on north branch of Spruce Run showing the undulating contact of the Bedford and Berea formations as indicated by the strips of paper and the hammer. Photograph by T. M. Hills.

SECTION ON SOUTHERN BANK OF SOUTH BRANCH OF SPRUCE RUN

No.		Thickness Feet	Total Thickness Feet
10.	*Berea sandstone.*—Old quarry near the top of the bank which contains layers of buff, fine-grained, quartz sandstone with numerous brown spots when weathered. Some of them are not very hard and weather to a decided brown color. Certain ones		

No.		Thickness Feet	Total Thickness Feet
	have a thickness of 11 in. and some are also ripple-marked. Rather more than 8 ft. of these layers are shown in the wall of the old quarry	8+	$40\frac{1}{2}$
9.	Buff, rather fine, quartz-grained sandstone, the layers generally varying from 3 to 10 in. in thickness; but some of them are rather thin or even shaly. It contains grains of marcasite and on weathering shows numerous brown spots	$13\frac{1}{2}$	$32\frac{1}{2}$
8.	Thin-bedded to shaly, buff sandstone	$1\frac{1}{4}$	19 +
7.	Sandy, buff shale	$2\frac{7}{12}$	$17\frac{5}{6}$
6.	Very fine, quartz-grained, buff sandstone zone, the lower part of which at the eastern end is somewhat contorted, apparently from concretionary action. On weathered surface this sandstone is not dark brown and rotten like the lower sandstones on this bank. The bottom of this sandstone is irregular, conforming to the irregularities in the surface of the underlying shale. This zone is considered the base of the Berea formation and is separated by a line of disconformity from the underlying shale	$1\frac{3}{4}$±	$15\frac{1}{4}$
5.	*Bedford formation.*—Blue, soft, argillaceous shale the upper surface of which is uneven, the zone varying in thickness from 2 to 6 in.	$\frac{1}{3}$±	$13\frac{1}{2}$
4.	Layer of calcareous, blue, very hard, compact sandstone which weathers to a brown color, and the rock becomes rotten. The layer varies from 4 to 5 in. in thickness. It contains $8\frac{1}{2}$ per cent of $CaCO_3$, and $MgCO_3$, which gives it a marked chemical difference from that of the superjacent Berea sandstone	$\frac{1}{3}$+	$13\frac{1}{6}$+
3.	Mainly blue, soft, argillaceous shale; but with an occasional thin, bluish (brownish as weathered) sandstone layer varying from $\frac{1}{2}$ to $1\frac{1}{2}$ in. in thickness	$3\frac{5}{6}$	$12\frac{5}{6}$
2.	Blue, very hard, compact, calcareous sandstone, weathering to a dark-brown color and becoming rotten. It tends to split into two layers and varies in thickness from 1 ft. 9 in. to 2 ft. It is strongly calcareous, containing 26.35 per cent of $CaCO_3$ and $MgCO_3$	$1\frac{5}{6}$+	9
1.	Blue, arenaceous and argillaceous shale alternating with layers of blue, hard, compact, calcareous sandstone, varying from 1 to $6\frac{1}{2}$ in. in thickness and some of them ripple-marked. Stream level	$7\frac{1}{6}$	$7\frac{1}{6}$

In the above section there is a very marked difference in the percentage of calcium and magnesium carbonates in the sandstones which are referred to the Bedford and Berea formations. The following table gives the analysis by Professor D. J. Demorest, of Ohio State University, of samples from zones 2, 4, and 6 of the above section.

	Zone No. 2 (1¾ to 2 ft. Sandstone, 4 to 5 ft. below Zone 6)	Zone No. 4 (4 to 5 in. Sandstone, 2 to 6 in. below Zone 6)	Zone No. 6 (Base of Berea)
	Per cent	Per cent	Per cent
$CaCO_3$	18.75	6.50	0.25
$MgCO_3$	7.60	2.00	0.00
Fe_2O_3	4.00	2.90	1.00
Quartz	52.80	59.10	76.00
Feldspar	4.40	9.30	8.00
Clay	8.40	20.60	14.50

An examination of the above table at once shows the high percentage of calcium and magnesium carbonates in the sandstones of zones Nos. 2 and 4, which are included in the Bedford, and the very small amount, only ¼ of 1 per cent, in the basal sandstone of the Berea. The sandstone layer almost at the very top of the Bedford, only from 2 to 6 in. below the base of the Berea or zone No. 6, contains 6½ per cent of $CaCO_3$ and 2 per cent of $MgCO_3$, or a total of 8½ per cent of these carbonates as against the ¼ of 1 per cent of $CaCO_3$ in the basal sandstone of the Berea. While in the thicker Bedford sandstone, zone No. 2, between 4 and 5 ft. below the base of the Berea the proportion is still more marked, since it contains 18.75 per cent of $CaCO_3$ and 7.60 per cent of $MgCO_3$, or a total of 26.35 per cent of these carbonates. This shows that more than one-fourth of the entire composition of this sandstone is composed of the calcium and magnesium carbonates, which clearly explains why this stone becomes rotten on weathering and the basal Berea with only ¼ of 1 per cent of $CaCO_3$ does not. Again, there is a marked increase in the amount of quartz in passing upward from the Bedford into the Berea, which is 52.80 per cent in zone No. 2, 59.10 per cent in zone No. 4 almost at the top of the Bedford, and 76 per cent in zone No. 6 at the base of the Berea. The percentage of quartz is almost 17 per cent greater in the basal sandstone of the

Berea than in the top one of the Bedford from 2 to 6 in. lower. This marked change in the chemical composition of the sandstones above and below the line of disconformity, together with that structure, is considered as proving that the line of separation between the Bedford and Berea formations occurs at the horizon of this line of disconformity.

The lower part of the above section is shown in Fig. 2. The hammer with the sheet of paper rests on top of the calcareous sandstone, zone No. 2, the upper calcareous sandstone near the top of the Bedford, zone No. 4, is just under the sheet of paper in the man's hand and above it is the basal, concretionary sandstone of the Berea, zone No. 6. Above the basal sandstone in ascending order may be seen the shale of zone No. 7, the thin-bedded to shaly sandstones of No. 8, and the lower layers of the continuous sandstones of No. 9.

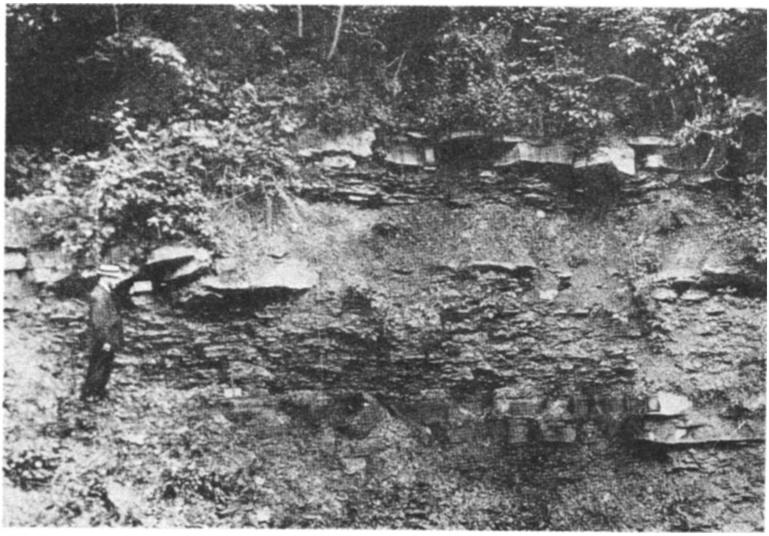

FIG. 2.—Southern bank on south branch of Spruce Run showing contact of Bedford and Berea formations. The hammer and sheet of paper mark the 1¾- to 2-ft. layer of calcareous sandstone in the Bedford and just above the sheet of paper in the man's hand is the base of the Berea. Photograph by T. M. Hills.

On the northern bank, a few rods farther up the stream, is another interesting outcrop, showing the contact of the two formations, only not so much of the upper part of the Bedford is exposed as on the southern bank.

UPPER SECTION ON NORTHERN BANK OF SOUTH BRANCH OF SPRUCE RUN

No.		Thickness Feet	Total Thickness Feet
6.	*Berea sandstone.*—Old quarries on upper part of bank containing buff-colored, rather fine-grained, quartz sandstone. Lower part of zone partly covered; but apparently continuous sandstone layers of moderate thickness	25¼	38¼
5.	Zone composed in the upper part mainly of arenaceous, blocky shale and in the lower part of contorted, buff, fine-grained, quartz sandstone. The contorted or concretionary sandstone in general varies in thickness from 0 up to 3 ft. 3 in. and even to the entire thickness of the zone. The concretionary or contorted sandstone also occurs at different levels in the shale zone. At two places the concretionary sandstone extends from the top of the Bedford shale clear up to the base of the apparently continuous sandstones, in other words, occupies the full width of this zone. Again a little above the lower end of the bank the concretionary sandstone fails altogether and the rather blocky, arenaceous shales extend from the top of the Bedford up to the base of the continuous sandstone with a thickness of 6½ ft. There is a lithologic difference, however, between the Bedford and Berea shales on this bank, the Berea containing fine grains of quartz sand. The base of this zone is considered the base of the Berea which is separated by a line of disconformity from the subjacent Bedford	6½	13
4.	*Bedford formation.*—Zone composed mainly of blue, soft, argillaceous shale with an occasional thin, arenaceous lamina. The upper surface is uneven; but near the lower end of the bank the zone is 11 in. thick	$\frac{11}{12}$	6½—
3.	Blue, very hard, compact, calcareous sandstone, weathering to a dark-brown color and becoming rotten, varying from 3 to 3¾ in. in thickness. This sandstone corresponds to zone No. 4 of the section on the southern bank, where it is from 4 to 5 in. thick; but with only from 2 to 6 in. of shale between it and the base of the Berea	¼	5½+

No.		Thickness Feet	Total Thickness Feet
2.	Blue, arenaceous and argillaceous shales with thin layers of blue, hard, compact sandstone from 1½ to 2 in. thick. Several of the thin sandstone layers are ripple-marked. This zone is 3 ft. 10½ in. thick and corresponds to No. 3 of the section on the southern side, which is 3 ft. 10 in. thick..................	3⅚+	5¼+
1.	Blue, very hard, compact, calcareous sandstone, weathering to a dark brown and becoming rotten. It splits into two layers and 1 ft. 5 in. is shown to water level at the lower end of the bank. Ripple-marks occur. This zone corresponds to No. 2 on the other side of the run, where it is from 1¾ to 2 ft. thick. Stream level..................................	1 5/12	1 5/12

Farther down the stream on the northern side is a considerably higher bank which was measured by Mr. Eugene Schmidt.

LOWER SECTION ON NORTHERN BANK OF SOUTH BRANCH OF SPRUCE RUN

No.		Thickness Feet	Total Thickness Feet
7.	*Berea sandstone.*—Buff sandstones, the layers of various thickness..............................	7¼	36¾
6.	Rather massive, buff sandstone, the lower part with contorted or concretionary structure and the upper part with thinner layers........................	2	29½
5.	Shale zone with some sandstone, 1½ ft. thick; but in some places apparently thicker.................	1½	27½
4.	Contorted or concretionary, buff sandstone zone with shale in middle. At the place measured 2+ ft. in thickness; but not so thick at all places on the bank. Irregular lower surface, forming the base of the Berea sandstone..............................	2 +	26
3.	*Bedford formation.*—Blue shale with thin layers of sandstone................................	3⅓	24 +
2.	Blue, sandstone zone which on the edge splits into thin layers, with a thickness of 2 ft. or more. This apparently corresponds to zone No. 1 of the section farther up the run and No. 2 of the one on the opposite side of the stream.....................	2 ±	20¾
1.	Blue, argillaceous and arenaceous shales with thin layers of blue sandstone from 1 to 4½ in. thick. Stream level..................................	18¾	18¾

Rocky Fork section.—This stream enters Big Walnut Creek not far below Gahanna, and various sections on its banks have been more or less fully described by the writer in former papers.[1] There has been some uncertainty where the line of division between the Bedford and Berea formations should be drawn and in his later papers the base of a concretionary sandstone has been considered as marking this horizon.[2] Later studies appear to support this conclusion and a very brief statement of these additional data will now be given. In former papers a section at the lower end of the gorge, where the basal part of the Berea is shown, and another one farther up the creek on the opposite and eastern bank, where the entire Berea formation occurs, have generally been described. On the western side of the stream, between the two cliffs mentioned above, is another one which will now be described.

SECTION ON WESTERN BANK OF ROCKY FORK

No.		Thickness Feet	Total Thickness Feet
4.	*Berea sandstone.*—Buff, quartz sandstone which forms upper part of cliff. Some of the layers are fairly thick; but more of them are thin-bedded....	26	$42\frac{1}{2}$
3.	Arenaceous shale changing to thin sandstone at top of zone. This shale is more sandy than that in zone No. 1 of the Bedford. The measurements for this zone have varied from 6 ft. 2 in. up to 7 ft. 8 in., depending upon the amount of thin-bedded sandstone at the top which has been included..........	$6\frac{3}{4}\pm$	$16\frac{1}{2}$
2.	Concretionary sandstone stratum composed largely of rather fine-grained, quartz sand. Varies in thickness from 1 ft. 10 in. to 2+ ft..............	2	$9\frac{3}{4}$
1.	*Bedford formation.*—The surface is somewhat irregular, indicating a line of disconformity between the two formations. Mainly blue, argillaceous shale with occasional thin layers of compact, blue, calcareous sandstone, which weather to a brown, rotten stone...	$7\frac{3}{4}$	$7\frac{3}{4}$

Samples were taken from a thin sandstone a few inches below the top of zone No. 1 and from the lower part of the concretionary sandstone, zone No. 2, which have been analyzed by Professor D. J. Demorest with the following result:

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[1] *Journal of Geology*, IX (1901), 216–18; *ibid.*, X (1902), 274–78; *American Geologist*, XXXIV (1904), 340, 341.

[2] *Journal of Geology*, X, 278; *American Geologist*, XXXIV, 340, footnote.

	Near the Top of Zone No. 1	Base of Zone No. 2 (Concretionary Sandstone)
	Per cent	Per cent
$CaCO_3$	16.5	1.6
$MgCO_3$	3.8	0.0
Fe_2O_3	5.1	2.0
TiO_2	0.2	0.2
Clay	17.4	11.2
Quartz	48.0	70.0
Feldspar	9.0	15.0

In the above analysis it will be seen that the thin sandstone a few inches below the top of zone No. 1 contains 20.3 per cent of calcium and magnesium carbonates, which a few inches higher in the base of the concretionary sandstone (zone No. 2) decrease to 1.6 per cent. On the other hand, the lower sandstone contains only 48 per cent of quartz, which in the base of zone No. 2 has increased to 70 per cent. The chemical composition of these sandstones, separated by only a few inches of shale, is decidedly different and strongly supports drawing the line of separation between the Bedford and Berea formations at the base of the concretionary sandstone as given above, where it had been placed on structural evidence.

The line of division between the Bedford and Berea formations is not so clearly shown on the next cliff on ascending the stream which is on its opposite side. The base of a sandstone layer varying from 4 to 6 in. in thickness, which in some places has concretionary structure and in others is broken and displaced, has formerly been considered the base of the Berea.[1] The concretionary layer of the lower bank is at about the same level as this sandstone as nearly as can be determined by hand level. Eleven to 16 in. below this 4- to 6-in. sandstone is a thinner one which perhaps should also be included in the Berea formation. The section of the lower part of this bank is as follows:

[1] *American Geologist*, XXXIV (1904), 340, footnote, No. 2 of section, and also see Pl. XVIII, Fig. 3, where the student stands on top of this sandstone.

SECTION ON EASTERN BANK OF ROCKY FORK

No.	Thickness Feet	Total Thickness Feet
5. Gray, fine-grained, quartz sandstone varying in thickness from 4 in. to 1 ft.	$\frac{10}{12}$ ±	6
4. Bluish shales which are quite arenaceous and contain some small sandstone concretions. These shales only slightly resemble those of the Bedford	$3\frac{7}{12}$	$5\frac{1}{6}$
3. Bluish-gray, compact, fine-grained, quartz sandstone, from 4 to 6 in. thick. This layer in places has concretionary structure and again it is broken and displaced. In former section given as the basal one of the Berea formation.[1]	$\frac{5}{12}$ ±	$1\frac{7}{12}$
2. Blue shales with some thin, sandy layers, the thicker ones ripple-marked. Zone varies from 11 to 16 in. in thickness	1 ±	$1\frac{1}{6}$
1. Compact, blue, fine-grained and thin-bedded sandstone which is ripple-marked and is $1\frac{3}{4}$ in. thick. This is a somewhat calcareous sandstone, as may be seen from the analysis, with a texture somewhat like the Bedford sandstones	$\frac{1}{6}$ −	$\frac{1}{6}$ −

These three sandstones were analyzed by Professor D. J. Demorest with the following result:

	Zone No. 1	Zone No. 3 (Former Base of Berea)	Zone No. 5
	Per cent	Per cent	Per cent
$CaCO_3$	5.1	1.4	0.8
$MgCO_3$	1.8	0.0	0.0
Fe_2O_3	4.4	2.0	2.0
TiO_2	0.2	0.2	0.2
Clay	18.5	13.4	13.0
Quartz	59.0	66.0	66.0
Feldspar	10.0	17.0	18.0

It will be seen from the above analysis that the calcium and magnesium carbonates (6.9 per cent) of zone No. 1 are lower than in the other analyses of Bedford sandstones of this region, while the amount of quartz is not greater than in some of them. In the two higher sandstones the amount of $CaCO_3$ diminishes from 1.4 per cent to 0.8 per cent, while there is no $MgCO_3$ and the quartz has increased to 66 per cent in each sandstone. It is to be noted that the amount of feldspar in the two upper sandstones is 17 and 18 per cent respectively, so that they may be termed arkose sandstones. These analyses apparently favor drawing the line of division between the Bedford and Berea formations at the same horizon, viz., the base of zone No. 3, as in the former section of this bank. Although the chemical change is not striking, still there is a marked decrease in the carbonates of the sandstones of zones Nos. 3 and 5 as compared with zone No. 1, while the upper sandstones have a larger percentage of quartz than the lowest one.

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[1] *American Geologist*, XXXIV (1904), 340, footnote, No. 2 of section.

Smith Run section.—In the northwestern corner of Fairfield County, 1¼ miles southwest of Lithopolis and about 4 miles south of Canal Winchester, is an interesting section on Smith Run, an eastern tributary of Big Run. Smith Run is about opposite the Nancy Cole house.

SECTION ON SMITH RUN

No.		Thickness Feet	Total Thickness Feet
6.	*Cuyahoga formation.*—Blue, fine-grained sandstones alternating with shales, some of the sandstone layers a foot or more in thickness	23⅔	83
5.	Two layers of fine-grained sandstone which are conspicuous on the southern bank	4⅓	59⅓
4.	Bluish to light-gray, argillaceous shale which varies in thickness from 5½ to 6⅓ ft. Two ft. 4 in. below the top of the shale is a 3½-in. layer of sandstone	6±	55
3.	*Sunbury shale.*—Thin, tough, even-layered black shale which is well shown in the narrow part of the glen. The measurements vary from 20⅔ ft. to 26⅔ ft. Specimens of *Lingula melie* Hall, *Orbiculoidea newberryi* (Hall) Herrick and fish scales occur about 3½ in. above its base and again abundantly at a horizon 4 ft. 8 in. above the base, near the top of the shale bank overlying the last outcrop of the Berea in going up stream	20⅔+	49
2.	*Berea grit.*—Rather coarse-grained, quartz sandstone which on the weathered surface is much stained, rusty, brownish or even blackish. The upper part contains much marcasite, so that the weathered top surface is pitted and rough, while it is much discolored or blackened. The cliff on the eastern side		

No.		Thickness Feet	Total Thickness Feet
	has a zone of marcasite at the base and it appears to be more or less common throughout the entire thickness. In the small gorge where the run cuts through the formation its entire thickness is shown on each side which varies from 1 ft. 11 in. to about 7 ft. 6 in. Its under surface is uneven, apparently corresponding to the inequalities in the upper surface of the underlying shale. The under surface of the Berea as shown on the western bank is decidedly irregular. From the point where the sandstone is lowest its base, or the top of the Bedford as it is followed up stream, rises 3 ft. 10 in. in a horizontal distance of 21 ft. At the lower end of the cliff where the sandstone has been exposed in recent years by a landslide the base of the Berea rises rapidly from its lowest point to a height of 5 ft. 8 in. and the sandstone is apparently reduced to a thickness of 1 ft. 11 in. In the small gully entering this gorge of Smith Run, just above the western cliff, the Berea is only 2 ft. 7 in. thick; while about 36 ft. farther west on the eastern bank of Smith Run it is about 7½ ft. thick. In all these outcrops it is the lower part of the Berea which thins and thickens, since the upper surface apparently remains uniform with the black Sunbury shale generally shown resting on it. There is no tendency to concretionary structure in the Berea sandstone at this locality and there is obviously a line of disconformity between the Berea and Bedford formations....................................	6½±	28½
1.	*Bedford shale.*—Soft, argillaceous, bluish-gray to gray shale on bank beneath the Berea sandstone. Farther down the run is chocolate, argillaceous shale which becomes mottled in color toward its mouth. The thickness varies from 22 to 27 ft., depending upon whether it is measured to the lowest or highest point of the under surface of the Berea. Water level of Big Run..............................	22	22

An earlier account of this section was published in the *American Geologist,*[1] together with a halftone of the western bank on which the disconformity in the contact of the Bedford and Berea formations is finely shown.[1]

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[1] XXXIV (December, 1904), 344, 345.

A view of the lowest outcrop of the Berea sandstone, as described in the above section, is given in Fig. 3. The student is indicating the lowest point, stratigraphically, of the base of the Berea which is seen to gradually rise as followed up stream. Below the sandstone is the soft, gray Bedford shale. At the line of the prominent joint in the Berea, a little farther down stream than the student, the base of the Berea rises rather abruptly, so that it is 5 ft. 8 in. higher than its lowest point. The base of this part of the Berea is clearly shown at the left edge of the picture. The top surface of the Berea is uniform all along this bank, showing that there has not been any settling of the blocks along the joint line.

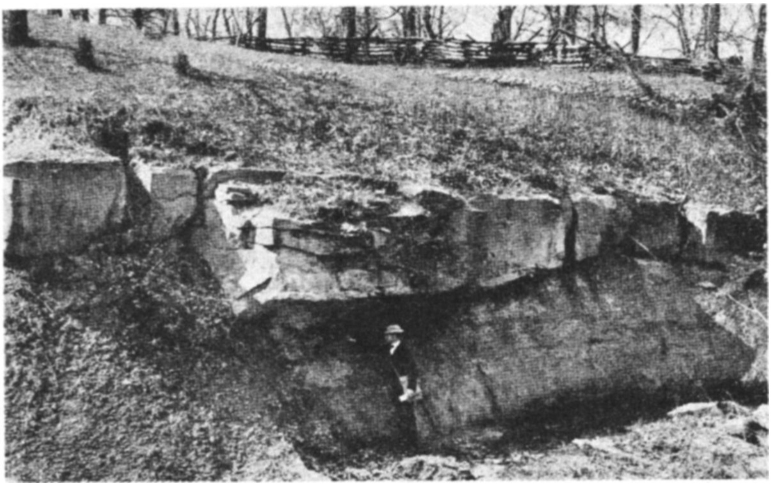

FIG. 3.—Disconformable contact of the Bedford and Berea formations on Smith's Run. Photograph by H. A. Gleason.

Slate Run section.—About 3½ miles southwest of Lithopolis or three-fourths of a mile northwest of Marcy on the farms of J. M. Hensel and Enos Zwayer in the northeastern corner of Pickaway County, an interesting section is shown along Slate Run.

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[1] *Ibid.*, Plate XIX, Fig. 6.

SECTION ON SLATE RUN

No.		Thickness Feet	Total Thickness Feet
5.	*Cuyahoga formation.*—Blue, fine-grained sandstones and some layers of soft, gray shale which contain but little grit. Thin-bedded sandstones with shales and shaly sandstones occur at the base, above which are shales containing concretions	25+	69+
4.	Gray, argillaceous shale which is very soft and gritless, with the exception of a 6-in. compact, gray sandstone, the base of which is 3 ft. 2 in. above the bottom of this zone	8⅔	44+
3.	*Sunbury shale.*—Thin, black, tough, laminated shale. The sharp contact of this shale with the superjacent, gray, Cuyahoga shale is finely shown in the bed of the run as well as the basal contact at the fall farther down stream with the subjacent Berea. The basal layer of this shale is arenaceous, strongly pyritiferous, and it contains numerous specimens of *Lingula melie* Hall. Different measurements of the thickness of this formation vary from 24⅔ to 26 ft.	26	35½
2.	*Berea sandstone.*—Composed principally of white, quartz sand of moderate coarseness, and forms a single stratum which varies in thickness from a little more than 1 ft. to 5 ft. The upper part contains plenty of marcasite and the weathered surface is pitted from its disintegration; but the surface is horizontal, not undulating. The lower surface is uneven and rough, with ridges which correspond to the thin sandstones in the underlying Bedford, while their faces represent the edges of the layers of soft shale, a character that at this locality Professor Thomas M. Hills first called to my attention. The rapid change in the thickness of this formation and the details of its contact with the Bedford formation are given more fully in the two following more detailed sections at this locality. There is no appearance of concretionary structure in the basal part of the Berea and there is a marked line of disconformity between the Berea and Bedford formations	5±	9½
1.	*Bedford formation.*—Mainly bluish, argillaceous shale with an occasional layer of thin sandstone from ¼ to 1 in. thick. At lower end of cliff with overlying Berea sandstone 4 ft. 7 in. to water level	4½	4½

Farther down the run are outcrops of the chocolate-colored, argillaceous, Bedford shales. Below these are excellent ones of the black Ohio shale, which in places form banks from 30 to 40 ft. in height. An earlier description of this section was given in the *American Geologist*.[1]

The least thickness of the Berea sandstone noted on this run occurs in the small fall on the Enos Zwayer farm, where the following section was measured at the fall's northern angle:

SECTION OF FALL ON SLATE RUN

No.		Thickness Inches	Total Thickness Feet, Inches
3.	*Sunbury shale.*—Basal portion of black, tough shale, the lower layers of which are rather arenaceous, pyritiferous, and tough; but containing near the base specimens of *Lingula melie* Hall and *Orbiculoidea newberryi* (Hall) Herrick..................................	7	2 7
2.	*Berea sandstone.*—Upper part not massive and containing much marcasite or iron pyrite. The sandstone in general is composed principally of white, quartz sand of moderate coarseness. The lower surface is rough, conforming closely to the inequalities in the upper surface of the underlying Bedford. At this point the Berea is thinnest and on the southern bank near that angle of the fall it is 2 ft. to 25 in. thick. This difference in thickness of the Berea is at the expense of the upper part of Bedford, since the upper surface of the Berea is even and regular with a dip up stream upon which the Sunbury black shale rests uniformly. Evident line of disconformity at the base...........	13½	2
1.	*Bedford formation.*—Bluish, argillaceous shale with an occasional, sandy layer, approximately ¼ in. thick. Level of stream..................................	10½	10½

A view of this angle of the fall is shown in Fig. 4, in which the lower hammer marks the disconformable contact of the Bedford and Berea formations, and the upper one the conformable contact of the Berea and Sunbury shale. The entire thickness of the Berea sandstone is shown, which is only 13½ in. at the corner or angle. It also clearly shows the thickening of the lower part of the Berea on the

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[1] XXXIV (December, 1904), 346–48.

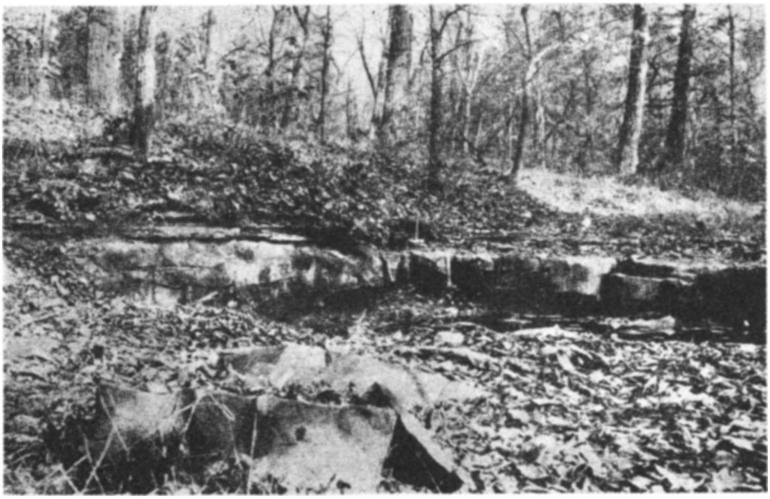

FIG. 4.—Fall on Slate Run showing entire thickness of Berea sandstone with Sunbury shale above and Bedford shale below. Each contact indicated by a hammer. Photograph by W. C. Morse.

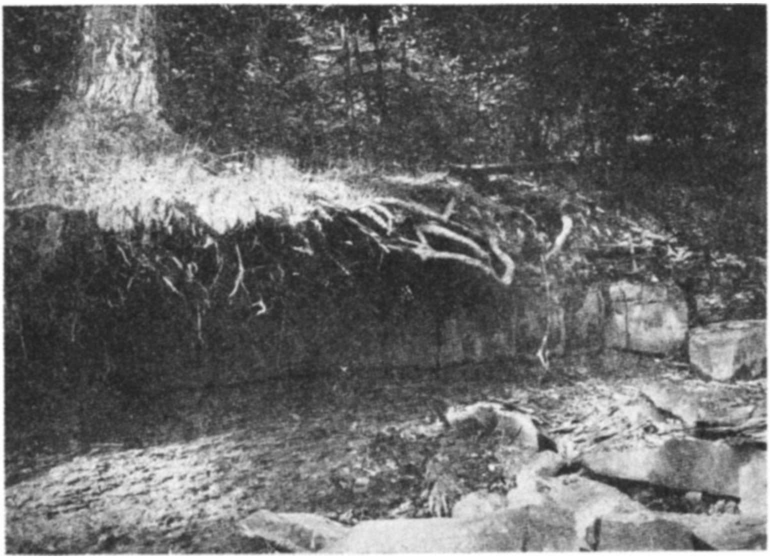

FIG. 5.—Entire thickness of Berea sandstone, with Sunbury shale above and Bedford shale below, on northern bank of Slate Run. Upper contact indicated by hammer. Photograph by C. S. Prosser.

northern bank as followed down stream, with the consequent decrease in thickness of the upper part of the Bedford.

On the northern bank, 6 ft. farther down stream than the angle shown in Fig. 4, the Berea has thickened from 13½ in. to 2 ft. and its base is stratigraphically lower than in the angle of the fall and cuts off some of the upper part of the Bedford. This is clearly shown by some of the thin sandstone layers, about ¼ in. thick, in the very upper part of the Bedford at the angle of the fall, which are cut off by the base of the Berea as it is followed down stream. Fifteen feet farther down stream from the point where the Berea is 2 ft. thick, it has increased in thickness to 2 ft. 4 in. Twenty feet farther down the run, nearly under the tree, the Berea has decreased from 2 ft. 4 in. to 15 in., and the upper part of the Bedford increased accordingly. This bank is shown in Fig. 5 where the hammer marks the contact of the Sunbury shale and Berea sandstone, below which the upper part of the Bedford shale is shown. At the fence 70 ft. farther down the stream and still on the same side, the Berea has thickened to about 5 ft. It again thins as followed down stream and 20 ft. below the fence at the lower end of the cliff it is only about 1 ft. 8 in. thick. In all this interval the upper surface of the Berea remains about uniform and the differences in thickness are due entirely to changes in its basal portion. The following section was measured at the lower end of the cliff farthest down stream:

SECTION OF LOWEST CLIFF ON SLATE RUN

No.		Thickness Feet	Thickness Inches	Total Thickness Feet	Total Thickness Inches
4.	*Berea sandstone.*—Composition similar to that in the other sections at this locality. It is only about 1 ft. 8 in. thick, but thickens rapidly as followed up stream. The lower surface is irregular and rough, corresponding to inequalities in the upper surface of the Bedford formation. No indication of concretionary structure. Conspicuous line of disconformity between the Berea and Bedford formations	1	8	5	3
3.	*Bedford formation.*—Bluish, argillaceous shale with occasional thin, arenaceous layers which a short distance farther up the bank are cut off by the descending base of the Berea sandstone..........	0	11	4	7

No.		Thickness		Total Thickness	
		Feet	Inches	Feet	Inches
2.	Arenaceous layer to thin sandstone, from ½ to ¾ in. thick, which in a horizontal distance of 4 ft. farther up stream is cut off by the base of the Berea. This shows a decrease in thickness of the upper part of the Bedford formation of about a foot in a horizontal distance of 4 ft. This bank is shown in Fig. 6 in which this layer is indicated by the hammer.......	0	1−	3	8
1.	Mainly bluish, soft, argillaceous shale with an occasional thicker and arenaceous layer. Level of water..................................	3	7+	3	7+

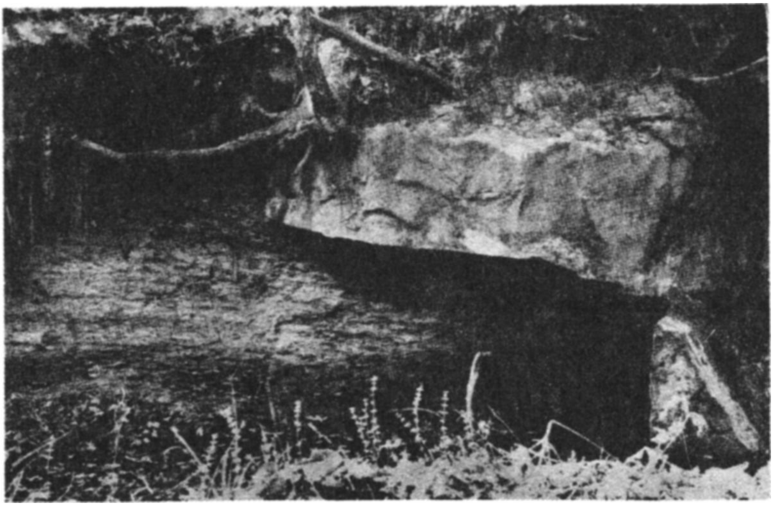

FIG. 6.—Disconformable contact of the Bedford and Berea formations on Slate Run. The hammer marks the thin Bedford sandstone, No. 2 of the section. Photograph by W. C. Morse.